

STAR FORMATION RATE AND ENVIRONMENT IN THE SDSS-DR4

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A. RIFATTO

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We investigate the environmental dependence of galaxies with the star formation rate (SFR) in a complete volume limited sample of 91566 galaxies, in the redshift range $0.05 \leq z \leq 0.095$, and with $M_r = -20.0$ (that is $M^* + 1.45$), selected from the Sloan Digital Sky Survey Data Release 4 (SDSS-DR4). The environment is characterized by the local number density of galaxies, defined by the parameter $\Sigma_N(\frac{N}{\pi * r_N^2})$, with $N=5$. We find a relation between the distance of the nearest neighbour and the SFR, and confirm the general trend for the SFR of decreasing with increasing density.

1. Introduction

There are many results showing that galaxy properties vary as a function of the environments. For example, one of the most fundamental correlation between the properties of galaxies and the environment in the local universe is the so-called morphology-density relation in clusters (e.g., Dressler 1980; Treu et al. 2003; Sorrentino et al. 2006) and its associated SFR - density relation (e.g., Lewis 2002). SFR also depends on the local density in groups and in the field. For example, using the Early Data Release (EDR) of the Sloan Digital sky Survey (SDSS), Gómez et al. (2003) found that the SFR - density relation also hold for field galaxies. Moreover, Balogh et al. (2004) used both the Two-Degree Field Galaxy Redshift Survey (2dFGRS; Colless et al. 2001) and the SDSS to show that the SFR of field galaxies is strongly dependent on the local projected density. All these results point to the existence of physical mechanisms that quench star formation as the local density increases, from the field to groups to clusters. This suggest that the morphology - density relation is not driven by processes that operate only in extreme environments, such as the core of rich clusters. In this paper we attempt to gain new insight into the nature of the previous relations, by studying how SFR depends on environment.

2. The SDSS-DR4

The SDSS (York et al. 2000; Abazajian et al. 2004) is a five-passband (u' , g' , r' , i' , z') imaging and medium-resolution ($R \simeq 1800$) spectroscopic survey of the northern Galactic hemisphere. In the DR4, the photometric area covers 6670 square degrees, while the spectroscopic area covers 4783 square degrees, providing spectra of about 10^6 galaxies, 10^5 quasars, 30,000 stars and 30,000 serendipity targets in the spectral range $3800 < \lambda < 9200 \text{ \AA}$, with a rms redshift accuracy of 30 km s^{-1} to an apparent magnitude limit (Petrosian magnitude) of $r' = 17.77$.

Spectroscopic data are obtained with a pair of multi-fiber spectrographs. Each fiber has a diameter of 0.2 mm ($3''$ on the sky), and adjacent fibers cannot be located more closely than $55''$ on the sky ($\sim 110 \text{ kpc}$ at $z = 0.1$ with $H_0 = 75 \text{ km s}^{-1} \text{ Mpc}^{-1}$) during the same observation. In order to optimize the placement of fibers on individual plates, and as the placement of plates relative to each other, a tiling method has been developed which allows a sampling rate of more than 92% for all targets. For details see the SDSS web site (www.sdss.org/dr4/algorithms/tiling.html).

Data have been obtained from the SDSS database (<http://www.sdss.org/DR4>) using the CasJobs facility (<http://casjobs.sdss.org/casjobs/>).

3. Sample selection

The SDSS-DR4 spectroscopic catalog is magnitude-limited, complete to the r-band magnitude $m_r = 17.77$. In order to avoid bias we have taken into account a complete volume-limited sample of galaxies in the redshift range $0.05 \leq z \leq 0.095$ and brighter than $M_r = -20.0$, that is $M^* + 1.45$. The lower redshift limit is chosen with the aim of minimizing the aperture bias (Gómez et al. 2003) caused by the presence of large nearby galaxies, while the upper limit was estimated through Schmidt's V/V_{max} test.

Our initial sample contains 91566 galaxies. For each galaxy, we computed its r-band absolute magnitude corrected for reddening and K factor, as suggested in Blanton et al. (2003). Galaxies with all the seven emission lines needed for the diagnostic diagrams (Kewley et al. 2001) and having $I_\lambda/\sigma_{I_\lambda} > 2$, where I_λ is the emission line flux and σ_{I_λ} its uncertainty, are classified as star forming galaxies (SFGs), according to the criteria adopted by Kewley et al. (2001). In order to avoid all the ambiguous cases in the AGN/SFG classification, we removed those sources whose line ratios fall close to the border line of the diagnostic diagrams. This was done by keeping only those sources for which part of the error bar associated to the logarithm of the line-ratios lies within the theoretical uncertainty of the model ($\sigma_{mod} = 0.1 \text{ dex}$) in both x and y directions. The final sample consists of 11754 SFGs.

4. SFR and Environment

For galaxies classified as star forming in the previous section, the SFR is evaluated using the H_α line, as in Hopkins et al. (2003):

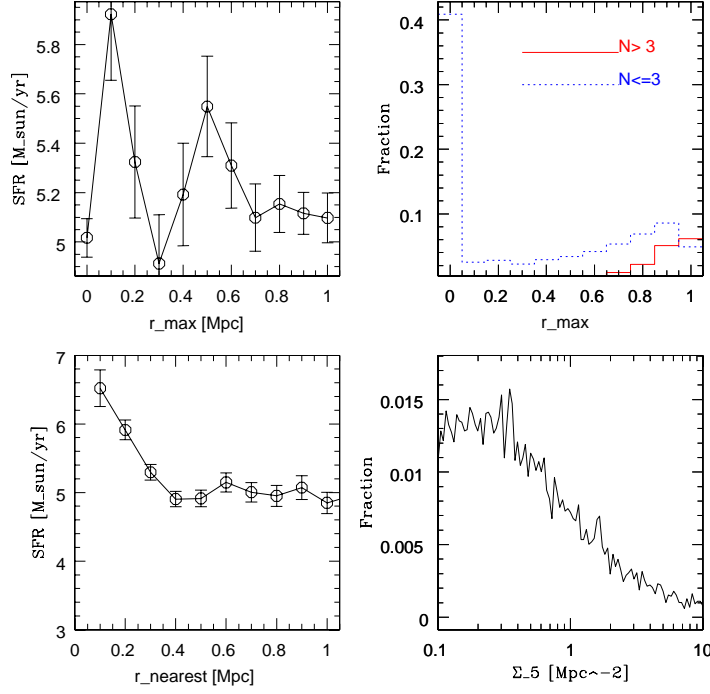


Figure 1. Top left panel: distance of the "most distant neighbours" (within 1 Mpc) versus the SFR. Top right panel: Neighbours number distribution with distance. Bottom left panel: distance of the "nearest neighbours" versus the SFR. Bottom right panel: galaxy density distribution.

$$\begin{aligned}
 SFR(H_\alpha) &= 7.9 * 10^{-42} L_{oc} \ M_\odot yr^{-1} \\
 &= (4\pi D_L^2 S_{H_\alpha}) * \frac{10^{-0.4(r_{petro}-r_{fiber})}}{1.27 * 10^{34}} \left(\frac{S_{H_\alpha}/S_{H_\beta}}{2.86} \right)^{2.114}
 \end{aligned} \quad (1)$$

The galaxy environment is defined by the Σ_5 density parameter, corresponding to the density evaluated for the fifth nearest neighbours, within 1 Mpc and with $\Delta cz \leq 1000 km/s$:

$$\Sigma_5 = \frac{5}{\pi * r_5^2} \quad (2)$$

The main results are summarized in Fig. 1. In particular, from the bottom left panel, it is evident that the SFR is enhanced by the presence of a close "nearest neighbour". In fact, the SFR has its maximum when the distance of the "nearest neighbour" is 0.1 Mpc. In the range from 0.1 to 0.4 Mpc it monotonically decreases and after 0.4 Mpc the SFR has no variations from the mean value of $\sim 5 M_\odot/year$. This result, similar to that found in previous works using the data from the 2dFGRS

(Lambas et al. 2003, Sorrentino et al. 2003), confirms that the presence of a close companion can trigger the SFR. Moreover, systems having an enhanced SFR are formed by a little number of companions, as it is evident in Fig.1 - top right panel, where systems with less than three companions are separated from systems with more than three companions. For distances closer than 0.4 Mpc, we find only poor systems. When we look at the large scale environment, we find a result that directly remembers the *morphology-density relation* (Dressler 1980). In fact, from Fig. 1 - bottom right panel, it is evident that the fraction of SFGs decreases with the environment, following a trend similar to the "morphology-density relation" for late-type galaxies. Then, this result suggests the existence of a *morphology-activity-density relation*, with three parameters instead of two (morphology-density).

5. Conclusions

In this paper we analyzed the environmental dependence of SFR in a complete volume-limited sample of SFGs in the SDSS-DR4. The environment is characterized by the local number density of galaxies, while the SFR is evaluated using the H_α line. Our findings can be summarized in the following points:

- (i) SFR is sensitive to the local galaxy density, in such a way that galaxies show higher levels of star formation in low-density than in high density environments.
- (ii) The presence of a close "nearest neighbour" enhances the SFR, which reaches the maximum value at the least distance of 0.1 Mpc and the minimum, constant value of $\sim 5M_\odot/\text{year}$ at distances equal or greater than 0.4 Mpc.
- (iii) The environmental properties of SFGs can be related to a *activity-density relation* in a such way that late-type galaxies are related to the *morphology-density relation*.

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